D2b.1 The potential of selected crops for production and use in target environment described

In the Mediterranean Region the introduction of new crops and cultivars with improved abiotic stress tolerance, especially for saline and drought stresses, could preserve water quality and soil resources from further degradation and provide extra sources of food for these areas.
In this context Quinoa, Amaranth and Lupins adaptation for food crop production in the Mediterranean Region have been studied.

Quinoa

Adaptation trials of quinoa (*Chenopodium quinoa* Willd) were performed in Morocco, Turkey and Italy. Quinoa, once an inferior crop grown in the Andes, has now become a popular an expensive commodity not least due to its high nutritional value. The seeds of quinoa are high in protein and contain an excellent balance of the amino acids comprising all the essentials to the human diet. It is an Andean seed crop cultivated in the Peruvian and Bolivian Andes for more than 7000 years. Quinoa is well adapted to grow under unfavourable soil and climatic conditions. In general, quinoa had higher economic and water saving values of seed and straw yields in new reclaimed sandy soils comparing to the results of wheat grain and straw yields.
In Morocco, a total of 78 quinoa accessions developed through recurrent selection from the Bolivian, Chilean and Peruvian genetic material introduced in 2000 to Morocco were evaluated on the basis of agro-morphological traits, performed under field conditions of Institute of Agronomy and Veterinary medicine IAV in Rabat Morocco. The aim was to evaluate the genetic diversity among developed germplasm of quinoa for proper utilization in breeding programs and select the most important traits to be used in the selection. This study revealed an extensive phenotypic diversity within the quinoa collection. The evaluation of the agro-morphological diversity through univariate and multivariate analysis pointed out the most performing genotypes, with *earliness, short plants* and *seed yield* being the main traits common to the advanced lines. Therefore they can be taken as relevant selection criteria for the quinoa national breeding program. Furthermore, accessions belonging to the same cluster and having desirable traits could be crossed to accessions from other clusters to gather favourable genes in one elite variety. Important differences among selected lines were observed in relation to yield, with the more productive line (L142) yielding 1890 kg/ha, twice the yield of the lowest producer (L123), which produced 910 kg/ha. Harvest index of quinoa ranged from 37 to 43,5%.
In Italy it was decided to include new quinoa cultivars resistant to abiotic stresses in the agricultural system of southern Italy in order to obtain new food products, with nutraceutical properties. Quinoa is a good source of different nutrients, is rich in antioxidants compounds and offers an alternative to cereals in coeliac diets because its seeds are gluten-free. Seven varieties were utilized (three from Bolivian seed producers and four from the collection of the University of Copenhagen. Comparing productivity among the seven quinoa varieties, Titicaca and Puno from Denmark showed the better yield, being more adaptable to the environment of Southern Italy. The highest harvest index (around 40%) was obtained in the variety Titicaca (U Copenhagen). Protein and lipid content was highest in Titicaca. These results suggest that both varieties could be cultivated successfully in Mediterranean climatic condition although more extensive field trials are required to develop optimal protocols for their cultivation. Chemical

composition of the Titicaca seeds shows that this variety can be successfully used as a food ingredient to develop new products with interesting nutritional and organoleptic properties. On the other hand, Puno is a potentially a better cultivar because of its high milling performance and the low content of total saponins. The alveographic indices showed that adding HDP inulin, the quality in terms of extensibility and the strength of dough resulted improved both in Titicaca and Puno. These first results gave useful information to improve and develop new quality products for celiac consumers, taking into account the enrichment of quinoa dough's with higher concentration of HDP inulin from cardoon, or mixing quinoa with other gluten-free flours.
The objective of the study in Turquey was to evaluate the yield response of quinoa (Titicaca) to salinity and drought stress under the Mediterranean climatic conditions. Quinoa grain yield obtained in trials performed in the experimental field of the Curukova University, Adana, was much higher than in Morocco with 3500 kg/ha in non-irrigated plots. WUE ranged from 0,3 to 0,7 kg/m3. The yield parameters such as above ground biomass, seed yield and HI suggested a good adaptation of quinoa to salinity and drought in the Mediterranean environment, so it can be considered a crop tolerant to stress. The effects of planting times and irrigation amount had significant effect on quinoa yield under Mediterranean climatic conditions in Turkey. Highest average seed yield was obtained from the full irrigation treatment with normal planting time. Higher water productivity was obtained from early planting time.
As for the seed quality of *Chenopodium quinoa* the milling performance, proteins, ashes, lipids and saponins of the seed were studied in the varieties Titicaca and Puno. A comparison of the compositional characteristics of the main gluten-free commercial flours was carried out (Tab. 1).

Table. 1 - Chemical composition of different gluten-free flours *(% DM)*

	Quinoa	**Riso**	**Mais**	**Buckwheat**
Protein	13.5 ± 0.06	7.6 ± 0.01	8.7 ± 0.09	10.9 ± 0.09
Lipid	5.5 ± 0.03	2.2 ± 0.04	1.8 ± 0.06	1.6 ± 0.01
Ash	3.10 ± 0.022	0.82 ± 0.014	0.45 ± 0.007	1.49 ± 0.028
Total fiber	9.3 ± 0.23	1.3 ± 0.07	3.1 ± 0.25	5.2 ± 0.36
Carbohydrates	68.6 ± 0.33	88.1 ± 0.19	86.0 ± 0.29	80.9 ± 0.52

Using quinoa flour, alone or in combination with flours buckwheat, (Tab. 2) leads to an improvement of the protein quality of the gluten free doughs. Lysine, limiting amino acid for most cereals, in quinoa dough was present in larger amounts, equal to 6.30 g/100 g of protein against 3.03 and 5.54 g/100 g of protein respectively for maize and rice. For the other essential amino acids, the low content of tyrosine, cystine and valine in quinoa is balanced by the presence of corn and rice flours.

Table 2 - Flour formulations for making pasta gluten-free

	Mixture 1	Mixture 2
Quinoa	10%	10%
Buckwheat	0%	10%
Rice	60%	50%
Mais	30%	30%

Both doughs with quinoa (Mixture 1 and Mixture 2) showed a composition comparable to the commercial pasta gluten-free except that the total protein content in the mixture 1 and 2 was greater than the commercial dough of quinoa alone. The chromatographic analysis of the amino acids has in fact highlighted the importance of balanced composition of flour to obtain products with an improved protein quality.

Amaranth

This crop was studied in Italy, at ISAFoM-CNR in Naples, with field experiments being conducted in Volturno river plain. Field experiments were carried out to study: a) the potential to introduce amaranth into the traditional cropping systems of southern Italy; b) agronomic responses of amaranth to different irrigation levels using saline and non-saline water. In general, yield responses of grain amaranth to different irrigation strategies showed values ranging from 0,7 ton/ha in rainfed plots to 2.5 ton/ha under irrigation. These differences were mostly associated with different sizes of leaf canopies.

A comparison between a fully irrigated treatment (control) and two deficit irrigation treatments (25 and 50% of the control) was performed, with irrigation water being either fresh water or saline water (ECw 22 dS m-1). Results showed that a reduction of 50% of irrigation volume of the control using either fresh or saline water did not cause a significant yield reduction with respect to full irrigated treatment. Amaranth should be considered moderately tolerant to salinity when the drought is more severe. The Maas and Hoffman model, applied both to the well irrigated treatments and to those irrigated in maximum drought stress conditions, indicates that the interaction effect of high drought and saline stress reduces amaranths' tolerance to ECe.

The chemical composition of amaranth seeds, starch, protein and ash content were significantly affected by the treatments. It was confirmed a higher protein content in amaranth seeds than in common cereals, together with high fat content.

Lupins

A multiplication and adaptation trial with 10 accessions Lupins (*Lupinus albus*) (was undertaken in Portugal. The different accessions exhibited large differences in phenology, namely in what concerns the beginning of flowering and the type of growth (determined versus undetermined) as well as in yield parameters, which ranged from 600 to 1600 kg/ha. The 642 genotype stands out from other genotypes in relation to production. Differences in growth and root morphology were also observed, in a study under controlled conditions using 6 genotypes from contrasting origins, with genotype 582 showing the highest total root length, volume and root surface area, with possible beneficial effects in terms of drought resistance. This genotype showed the second highest production under field conditions, around 1400 kg/ha. No significant differences were observed in the photosynthetic performance, which suggest that the yield potential may be more dependent on total LAI, the character of determined versus undetermined

growth or the harvest index. These are traits to be looked for in future studies. Seed quality parameters - protein, fat, %C and N, galactans, alpha-galactosides and starch were measured in the ten lines. A large range of values were observed, depending on the line and the year.

In conclusion: Introduction of drought and salt tolerant crop species such as quinoa, amaranth and lupin may result in more resilient crop rotations and high value cash crop products.

Our study showed that quinoa can be of high value for growing in the Mediterranean environment since it can be considered a crop tolerant to stress. An extensive phenotypic diversity was revealed within the quinoa collection (78 accessions) studied in Morocco. The evaluation of the agro-morphological diversity through univariate and multivariate analysis pointed out the most performing genotypes, with *earliness*, *short plants* and *seed yield* being the main traits common to the advanced lines. Therefore they can be taken as relevant selection criteria for the quinoa national breeding programs in the Mediterranean region. Comparing productivity among the seven quinoa varieties studied in Italy, Titicaca and Puno showed the better yield, being more adaptable to the environment of Southern Italy. As a food ingredient, chemical composition of the Titicaca seeds shows that this variety can be successfully used to develop new products with interesting nutritional and organoleptic properties. Puno is a potentially better cultivar because of its high milling performance and the low content of total saponins. The introduction of 10% quinoa in mixtures with rice or maize showed a composition comparable to the commercial pasta gluten-free except that the total protein content was greater than the commercial dough of quinoa alone. Overall, our results gave useful information to improve/develop new quality products for celiac consumers, taking into account the enrichment of quinoa doughs with higher concentration of HDP inulin from cardoon, or mixing quinoa with other gluten-free flours.

Amaranth should be considered moderately tolerant to salinity, especially when the drought is more severe. It was confirmed a higher protein content in amaranth seeds than in common cereals, together with high fat content.

As for lupins, large differences in phenology, namely in what concerns the beginning of flowering and the type of growth (determined versus undetermined) as well as in yield parameters, which ranged from 600 to 1600 kg/ha were observed in the collection studied. This leads to a high potential for adaptation in the Mediterranean area.

Future prospects: In the new crops, genotypic increases may arise from selection for early vigour, deep roots, increased transpiration efficiency, improved disease resistance, and high assimilate storage and remobilization. A range of crop and management strategies might be combined for a specific target environment in order to optimize crop productivity. These combinations can then be used as a guidance to future decision support systems for crop production at limited water supply under arid Mediterranean conditions.